STATE OF CALIFORNIA
The Resources Agency

Department of Water Resources

in cooperation with

Santa Clara Valley Water District

BULLETIN No. 118-1

EVALUATION OF GROUND WATER RESOURCES: SOUTH SAN FRANCISCO BAY

Volume III: NORTHERN SANTA CLARA COUNTY AREA

DECEMBER 1975

CLAIRE T. DEDRICK
Secretary for Resources
The Resources Agency

EDMUND G. BROWN JR.
Governor
State of California

RONALD B. ROBIE
Director
Department of Water Resources

STATE OF CALIFORNIA
The Resources Agency

Department of Water Resources

in cooperation with
Santa Clara Valley Water District

BULLETIN No. 118-1

EVALUATION OF GROUND WATER RESOURCES: SOUTH SAN FRANCISCO BAY

Volume III: NORTHERN SANTA CLARA COUNTY AREA

Copies of this bulletin at $3.00 each may be ordered from:
State of California
DEPARTMENT OF WATER RESOURCES
P.O. Box 388
Sacramento, California 95802
Make checks payable to STATE OF CALIFORNIA
California residents add sales tax.

DECEMBER 1975

CLAIRE T. DEDRICK
Secretary for Resources
The Resources Agency

EDMUND G. BROWN JR.
Governor
State of California

RONALD B. ROBIE
Director
Department of Water Resources

FOREWORD

The South San Francisco Bay Ground Water Basin, which includes portions of Alameda, San Mateo, and Santa Clara Counties, underlies the southern portion of San Francisco Bay and its gently sloping bayshore plains. The ground water basin has been divided into three subbasins: the Fremont study area, encompassing the Alameda Creek-Niles Cone area and reported on in Volumes I and II of Bulletin No. 118-1, published in 1968 and 1973, respectively; the San Mateo study area, which includes the western shore of the bay; and the North Santa Clara County area, which is the subject of this volume of Bulletin No. 118-1.

Ground water has played an important part in the development of the Santa Clara Valley area since the first settlers arrived in 1777. As water needs exceeded supplies, most of the surface water runoff was controlled by reservoirs and released for ground water recharge. By the year 1950, almost all of the valley's water needs were met by water pumped from the underlying ground water basin, which was operated in conjunction with surface water storage. This development sent water levels to an all-time low of over 150 feet (46 meters) below the ground surface.

Imported water supplies have been available to the area since 1950 from the City of San Francisco's Hetch Hetchy Aqueduct and since 1965 from the State Water Project's South Bay Aqueduct. During the period 1965-1970, the amount of ground water in storage has increased about 60,000 acre-feet (74 cubic hectometers) a year. The local agency is now reaching the upper limit of its imported water entitlement. Increasing use of water will reduce additions to ground water in storage, and by the 1980's will bring about increasing depletion of ground water in storage unless corrective measures are taken.

This report contains an evaluation of the geologic and hydrologic characteristics of the ground water reservoir and describes the mathematical model developed to simulate the ground water system.

Recommendations are made with regard to a new monitoring well network which will accurately define water levels with respect to the aquifer system. This, in turn, will allow a more accurate determination of changes in the amount of ground water in storage and increase the accuracy of the model.

The study was conducted in cooperation with the Santa Clara Valley Water District. Results of the study will be used by the cooperating agencies to evaluate alternative management plans using surface, ground, and waste waters and for evaluation of artificial recharge sites and pumping pattern changes.

Ronald B. Robie

Ronald B. Robie, Director
Department of Water Resources
The Resources Agency
State of California

TABLE OF CONTENTS

Page

TABLES

FIGURES

STATE OF CALIFORNIA
Edmund G. Brown Jr., Governor

THE RESOURCES AGENCY
Claire T. Dedrick, Secretary for Resources

DEPARTMENT OF WATER RESOURCES
Ronald B. Robie, Director
Robin R. Reynolds, Deputy Director

CENTRAL DISTRICT

Wayne MacRostie . . . . Chief

This investigation was conducted
under the supervision of

Donald J. Finlayson . . . . . Chief, Water Utilization Branch

by

Robert S. Ford . . . . Senior Engineering Geologist
William B. Mitchell, Jr. . . . . Senior Water Quality Engineer
Larry Chee . . . . Associate Engineer
James Barrett . . . . Assistant Engineer

In cooperation with

SANTA CLARA VALLEY WATER DISTRICT

LLOYD FOWLER, Chief Engineer

Under the supervision of

David K. Gill . . . . Advanced Planning Manager

by

Eugene S. Watson . . . . Senior Civil Engineer
Thomas I. Iwamura . . . . Engineering Geologist
T. Pandit . . . . Associate Civil Engineer
Hirendra Majumdar . . . . Associate Civil Engineer
Randall Talley . . . . Associate Civil Engineer

State of California
Department of Water Resources
CALIFORNIA WATER COMMISSION

IRA J. CHRISMAN, Chairman, Visalia

CLAIR A. HILL, Vice-Chairman, Redding

Mal Coombs	Garberville
Ray W. Ferguson	Ontario
Ralph E. Graham	San Diego
Clare Wm. Jones	Firebaugh
William P. Moses	San Pablo
Samuel B. Nelson	Northridge
Ernest R. Nichols	Ventura

Orville L. Abbott
Executive Officer and Chief Engineer

-----0-----

SANTA CLARA VALLEY WATER DISTRICT

JOHN T. O'HALLORAN, General Manager

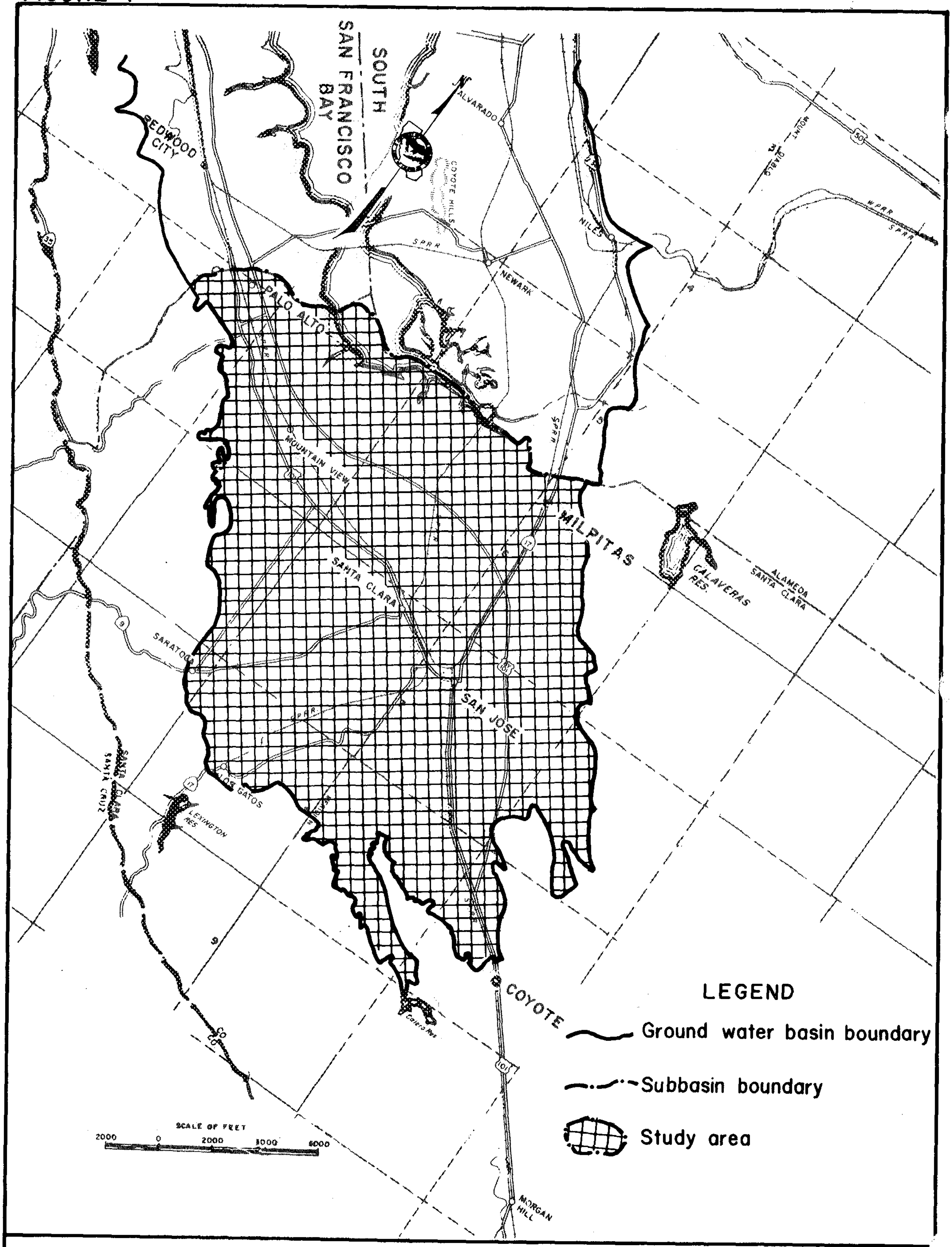
DISTRICT BOARD OF DIRECTORS

Robert T. Sapp, Chairman

Marice E. Dullea
Patrick T. Ferraro
James J. Lenihan

Edmund A. Mirassou
Courtland M. Rush
Joseph Chiri

FIGURE 1



AREA OF INVESTIGATION

CHAPTER I. INTRODUCTION

Since the settlement of Santa Clara County nearly 200 years ago, water has played an important role in the development and economy of the area. The development of an economy based on agriculture, particularly orcharding, and the start of urban development in the early part of this century was based almost exclusively on water pumped from the ground water body. In the years since 1950, local conservation projects and imported water supplies have been utilized in a race to keep up with continually increasing demands for water, and it is expected that even more water supplies will be required by 1980.

During periods when water demands exceeded supplies, the difference was met by overpumping of the ground water basin. When this adverse situation existed for more than just a few years, water levels fell to a point that permitted land subsidence to occur in the area surrounding South San Francisco Bay. Lands thus lowered by subsidence subsequently became subject to flooding from flood runoff and high tides and had to be protected by an extensive levee system.

Santa Clara County is a major water-consuming area, and it uses water supplies from both conservation reservoirs and ground water reservoirs. The effective use of water resources in the county is the concern of both state and local agencies because a part of the county's water supply is imported through the State Water Project and the Hetch Hetchy system of the City of San Francisco.

To obtain adequate information for the preparation of a series of water resource development plans, the State Department of Water Resources entered into an agreement with the Santa Clara Valley Water District to study the water resources of Santa Clara County. This bulletin presents in detail the geohydrologic conditions which affect the occurrence and movement of ground water in the northern part of Santa Clara County. The cooperative agreement is based on a 50-50 sharing of the costs of the study and has included full participation of the staffs of both agencies. A similar study is in progress covering the southern portion of the county. Additional studies of a wide range of management plans for both the north and south parts of the county will be made following the conclusion of the geohydrologic studies. Parallel studies by both agencies on possible use of waste water reclamation to extend the utility of present water supplies have been coordinated over the past two years and are continuing. Furthermore, a water quality management study is being conducted by the two agencies on a cooperative basis to provide information on cause-effect relationships and to form a basis for alternative water quality management plans.

The results of studies by the Department and the District are published so that information is available to local government representatives for consideration in adopting objectives, policies, and plans relative not only to water resource management, but also to other water-related resources.

Area of Investigation

The area of investigation comprises the southern part of the South Bay ground water basin, as shown on Figure 1. The basin is bounded on the west by the Santa Cruz Mountains and on the east by the Diablo Range; these two ranges converge at Coyote Narrows to form the southern limit of the basin. The south part of the basin, the subject of this bulletin, includes northern Santa Clara County and adjacent portions of Alameda and San Mateo Counties.

The northern boundary of the immediate study area, just north of the Santa Clara County line as shown on Figure 1, was chosen for two reasons: (1) it represents the boundary of a manageable ground water unit, and (2) it delimits the depositional area of influence of Coyote Creek, Guadalupe River, and others which drain northerly into San Francisco Bay.

The southern boundary of North Santa Clara Valley, as used in this bulletin, differs from that used in State Water Resources Bulletin No. 7, "Santa Clara Valley Investigation". That bulletin identified the ground water divide near Morgan Hill as the southern boundary of the basin. In this bulletin, the constriction of the water-bearing materials at Coyote Narrows, one mile north of the community of Coyote, is used as the southern boundary of the ground water basin.

Previous Investigations

Ground water has been and continues to be a major source of water for domestic, irrigation, and municipal uses in Santa Clara County. Interest in this subsurface source of water has resulted in the publication, since 1915, of seven significant reports covering all or parts of the present study area. These seven reports, and other geologic reports pertaining to the area, are listed in Appendix B, "Bibliography".

The drastic lowering of ground water levels prior to the 1920's, which resulted from heavy pumping draft, prompted Tibbetts and Kieffer (1921) to prepare the publication, "Report to Santa Clara Valley Water Conservation Committee on Santa Clara Valley Water Conservation Project". This report recommended the establishment of a water conservation district, the construction of dams and surface water conveyance facilities, and the extensive use of artificial recharge of ground water. The recommendations subsequently were adopted, and the facilities which were constructed allowed ground water levels to recover.

The Tibbetts and Kieffer report was followed by Clark (1924), who reported in some detail on the ground water conditions in Santa Clara Valley in U. S. Geological Survey Water-Supply Paper 519, "Ground Water in Santa Clara Valley, California". In this study, Clark included all of the present study area together with that portion of Santa Clara Valley south of Coyote Narrows.

In 1933, the California Division of Water Resources (predecessor to the Department of Water Resources), in response to a request by the newly established Santa Clara Valley Water Conservation District, published Bulletin 42, "Santa Clara Investigation". This bulletin described the historic decline of ground water levels, the amount of ground water depletion, and the quantity of replenishment from surface streams in the area.

The Division of Water Resources again studied that portion of Santa Clara Valley Ground Water Basin underlying Santa Clara County during the period from 1948 to 1954. In this latter investigation, considerable knowledge of the geologic conditions governing the movement of ground water was obtained in both North and South Santa Clara Valley, and the results were published in June 1955 as State Water Resources Board Bulletin 7, "Santa Clara Valley Investigation".

The history of land subsidence in the Santa Clara Valley was summarized by Poland and Green (1962) in U. S. Geological Survey Water-Supply Paper 1619-C, "Subsidence in the Santa Clara Valley - A Progress Report". This brief paper relates subsidence to geology and pumpage of ground water. Material presented in this paper was updated by Poland in 1971 with the publication of U. S. Geological Survey, San Francisco Bay Regional Environment and Resources Planning Study, Technical Report 2, "Land Subsidence in the Santa Clara Valley, Alameda, San Mateo, and Santa Clara Counties, California".

From 1962 to 1965, the Department conducted a geologic investigation of the South San Francisco Bay area and published its findings in August 1967 as Bulletin 118-1, "Evaluation of Ground Water Resources, South Bay, Appendix A: Geology".

The appendix describes in some detail the geology of the water-bearing sediments in the southern part of the San Francisco Bay area, which includes portions of Alameda, Santa Clara, and San Mateo Counties. Information presented is intended to support subsequent studies in the hydrology, water quality, and operational characteristics of the ground water basin. Included in the appendix is a brief discussion of the geologic history which relates the succession of significant geologic events in the area of investigation. Also included is a chapter on the geologic formations and their water-bearing characteristics. In this chapter are described the geologic materials that make up the basin, as well as the aquifers and confining beds that have been identified within them. The lithology of the more permeable Holocene and Pleistocene sediments is discussed. The older, underlying rocks, which generally are nonwater-bearing, also are briefly discussed. Structural features, such as faults, are discussed along with their relation to ground water movement.

The various exploratory phases of the investigation are described in the appendix, and there are brief sections on the collection and analysis of geologic and geophysical data, the drilling of test holes, and the installation of piezometers.

Finally, the physical and water-bearing characteristics of the various ground water areas, with their respective subareas, are discussed in detail. The discussion includes the location of boundaries and description of extent, thickness, lithology, and water-bearing character of aquifers and confining beds within each subarea.

History of Water Use

Water has played a large and important role in the development of the valley portions of Santa Clara County since the first settlers arrived nearly 200 years ago. With the founding of Mission Santa Clara de Asis along the Guadalupe River by Franciscan padres in 1777, the valley was given its name. Later that same year, Pueblo de San Jose was founded nearby, making it the first civil settlement in California.

The valley has had four distinct periods of economic development and land use: cattle raising, grain farming, fruit production, and the present period of industry and urbanization. In the early part of the last century, cattle ranching was the principal activity in the valley. Following the gold rush, cattle ranching gave way to grain farming. In 1856, Pierre Pellier discovered that the climate and soil of Santa Clara Valley were ideal for raising prunes. By 1870, the prune became nationally popular, and valley farmers began intensive production of this and other deciduous fruits. Subsequently, the Santa Clara Valley became known as the dried fruit and the canning fruit center of the world. The acreages of fruit and nut trees increased tremendously, from 20,000 acres (8,100 hectares)* in the late 1880's to 110,000 acres (44,000 ha) in 1930. The water required to irrigate the orchards had a dramatic impact on local water supplies, and the draft upon the underground water resources of the valley was unprecedented. In 1934, water levels fell to 140 feet (43 meters) below the ground surface, in a valley which once had over 2,000 flowing artesian wells.

*Metric unit equivalents are shown thus (   ). See Appendix C for equivalents.

The present municipal and industrial period began with the large influx of families and industry into the valley following World War II. The population surged to 291,000 in 1950 and by 1965 had more than tripled to over 900,000. This growth alone made water demands climb, but in addition, the per capita consumption increased 40 percent between 1950 and 1970, creating water needs that were phenomenal. By 1970, the water requirements of the north valley alone were nearly 250,000 acre-feet (308 cubic hectometers)*.

In 1950, most all of the valley's water requirements were met by water pumped from the underlying ground water basin. This stress on the basin sent water levels to an all-time low of over 150 feet (46 m) below the ground surface. To replenish the depleted ground water supply, the Santa Clara Valley Water District constructed eight conservation reservoirs with a combined capacity of over 150,000 acre-feet (185 hm^3). The reservoirs capture the runoff from winter rains and store the water until it can be released into streams and percolation ponds for recharge of the ground water basin.

The initial stages of the Hetch Hetchy Aqueduct were constructed by the City of San Francisco in 1934-35. However, it was not until 1952 that an 80 MGD (303,000 m^3/d) extension of the Hetch Hetchy System was completed across the northern Santa Clara Valley, where it now supplies water to Sunnyvale, Palo Alto, Mountain View and Milpitas. Hetch Hetchy imports have increased steadily, and were nearly 50,000 acre-feet (62 hm^3) in 1973.

When it became evident that the combination of Hetch Hetchy and local water supplies could not meet the water demands, plans were made to acquire additional water from sources outside the valley. The Santa Clara Valley Water District contracted with the State in 1961 to receive 88,000 acre-feet (109 hm^3) of water annually through the South Bay Aqueduct of the California Water Project through 1988. By 1994, the District is scheduled to receive a maximum of 100,000 acre-feet (123 hm^3) per year. Deliveries to the north valley began in July 1965 and have totaled 100,000 acre-feet (123 hm^3) a year. This quantity is composed of 88,000 acre-feet (109 hm^3) of contracted water and an additional 12,000 acre-feet (15 hm^3) of surplus water when available. Approximately half of this state water is treated for surface distribution. The remainder is used for artificial recharge of the ground water basin. Ground water levels have been recovering since the initiation of water importation through the South Bay Aqueduct.

Most of the increase in water demands are now supplied by treated imported water, and ground water production has remained relatively constant at approximately 150,000 acre-feet (185 hm^3) per year. Ground water supplied more than 96 percent of the water needs

* Cubic hectometer (hm^3) = 1 million cubic meters.

of Santa Clara County in 1950. In the south county area, all of the water needs are still met from ground water, while in the north county area, ground water now supplies only 60 percent of the total water demand.

The Penitencia Water Treatment Facility was completed in 1974 by the Santa Clara Valley Water District. This 20 MGD (76,000 m^3/d) plant treats South Bay Aqueduct water and, with the Rinconada Water Treatment Plant, completed in 1967, eventually will be treating nearly 70 percent of the total South Bay Aqueduct import.

Recent water demand projections indicate that demand will again equal or exceed supplies in the north part of Santa Clara County beginning in about 1978. The Santa Clara Valley Water District is presently considering alternative water supply sources to satisfy this additional need for 145,000 acre-feet (179 hm^3) of water. Emphasis is on efforts to secure this water from the San Felipe Division of the Federal Water Project, although the District is continuing to study local projects, waste water reclamation, and water-saving devices and practices.

Current Investigation

The desired result of the geohydrologic phase of the study is a verified mathematical model of the ground water basin. Early in the study the need for further geologic work became apparent with regard to additional detail on aquifer systems previously identified as heterogeneous mixtures of aquifers and confining beds. The need for a refined geologic analysis was met by the development of a statistical approach to the examination of the large quantity of subsurface data available. The major additions to geologic knowledge made by this study are listed in Chapter III and include the results of a detailed analysis of the well drillers' logs to obtain a three-dimensional concept of the subsurface. The results are presented as (1) a contour map of the base of the water-bearing deposits, (2) locations of buried stream channel deposits, and (3) geologic cross sections of the ground water basin.

Chapter IV contains the hydrology in the form of an inventory, or accounting, of the amounts of recharge to and withdrawals from the ground water basin on an annual basis and explains the methods used to obtain numeric values. The simulation of the ground water system by a mathematical model, comparison of the inventory with change of ground water in storage, adjustment of the inventory and verification of the model are also reported. An analysis of historic data needs, as well as data requirements for present and future water resource management, is discussed in Chapter V, along with general criteria for development of water resource surveillance networks.

CHAPTER II. CONCLUSIONS AND RECOMMENDATIONS

The conclusions of the geologic and hydrologic evaluations of the ground water system in north Santa Clara County are set forth below. Recommendations for the further refinement of these conclusions are shown at the end of this chapter.

Conclusions of the Geologic Evaluation

The detailed study of the aquifer system in the north part of Santa Clara County identified and delineated a number of geologic features hitherto unknown. A discussion of these features appears in Chapter III of this bulletin; geologic conclusions, based on these features, are enumerated below:

1. Most streams draining the highland areas surrounding Santa Clara Valley have flowed across the valley floor at roughly their present locations for the past several million years.

2. Only a few streams have had major shifts in their channel locations, and these shifts have been due primarily to the geologic phenomenon called stream capture.

3. Former courses of streams occur today as buried channels composed of sand and gravel enclosed in finer-grained silt and clay.

4. Buried stream channels, which act as water-bearing conduits, are not continuous, but they have been separated into discrete segments due to post-depositional erosion and fault movement.

5. The periodic rise and fall of sea level has had a marked effect on the location and extent of the now-buried stream channels. During periods when the sea stood at a high level, beds of marine clay were deposited over older stream channel deposits. These now act as widespread confining beds to ground water contained in the underlying stream channel deposits.

6. The Santa Clara Valley apparently has been slowly subsiding during the past five to eight million years. This is suggested from the identification of stream channel deposits at a depth of 550 feet (168 meters) below present sea level.

7. There are a great many faults crossing the floor area of Santa Clara Valley; a number of these had not been previously identified. Although the direction and amount of displacement could not be determined, several of the faults appear to have displaced sediments within 50 feet (15 meters) of the present ground surface.

Conclusions of the Hydrologic Evaluation

During the study period 1962-63 through 1969-70, the total increase in the amount of ground water in storage was about 330,000 acre-feet (407 hm^3), and the precipitation as measured at San Jose was eight percent above the long-time average. Also, during the study period, the total amount of water imported from the City of San Francisco Hetch Hetchy system and the State Water Project South Bay Aqueduct was about 540,000 acre-feet (666 hm^3). Without imported water supplies, the ground water basin would have suffered a net loss of ground water in storage of in excess of 210,000 acre-feet (259 hm^3). The basin also would be experiencing severe effects of continued land subsidence, and, in all probability, certain areas would have experienced water quality degradation from the upward movement of connate waters and the inland movement of salt water from the bay.

The levying of a ground water pump tax in 1965 has substantially reduced the amount of water being applied to acreage used for irrigated agriculture and orcharding.

Average recharge to the ground water basin during the 8-year study period was about 190,000 acre-feet (235 hm^3) per year. About 60 percent of the total replenishment to the ground water body is through the percolation of conserved and imported water in improved streambeds and percolation ponds.

In spite of its limitations, the mathematical model was found to be very useful as a tool to test the effectiveness of the various concealed faults on the movement of ground water. It is concluded that these concealed faults are not effective barriers in areas where major streams have existed throughout geologic time.

Recommendations

It is recommended that the Santa Clara Valley Water District:

1. Complete verification of the ground water model developed in this study by:

    a. Redesigning its data collection system on the basis of the geologic and hydrologic information in this bulletin. A suggested water level measurement network is presented in Chapter V. The design of a compatible water quality surveillance network is proceeding under a separate co-operative program.

b. Testing the accuracy of the ground water model with the data collected during the first three to five years of operation of the redesign data collection system.

2. Use the model without waiting for verification to test the general response of the ground water system to a variety of alternative conjunctive operation plans.

3. Continue to cooperate with other local water agencies in conjunctive operations of the water resources of the area.

4. Take measures to assure that damaging overdraft does not recur by securing new sources of water as needed and obtaining necessary legal authority to prohibit damaging overdraft.

CHAPTER III. GEOLOGIC FEATURES

The various geologic formations of the northern part of Santa Clara County may be divided into two basic groups for the purpose of ground water studies. Consolidated rocks, which range in age from Jurassic to late-Tertiary and in composition from marine sediments to volcanic rocks and serpentine, comprise the nonwater-bearing series. These rocks produce relatively small quantities of water from fractures and seams; the water may be of unpotable quality. By far the most important geologic materials in the Santa Clara Valley area are those of the water-bearing series. These range from Pleistocene to Holocene in age and consist of a thick sequence of valley-fill material ranging in composition from sand and gravel to silt and clay. Nearly all of the water wells in Santa Clara Valley derive their supply from the water-bearing series. All of the nonwater-bearing and water-bearing materials are briefly described below. A detailed description of these materials, as well as a geologic map depicting their surficial extent, appeared in Appendix A to this bulletin, which was published separately in August 1967.

Nonwater-Bearing Series

Rocks of the nonwater-bearing series are exposed in the Santa Cruz and Diablo Mountains and also in the hills that rise above the alluvial plain of Santa Clara Valley. These rock types underlie all of the valley-fill materials at depths ranging from less than 100 feet (30 meters) to over 1,500 feet (460 meters). They mark the lower limit of ground water production in Santa Clara Valley and also define the bottom of the ground water basin. The geologic formations which comprise the nonwater-bearing rocks are composed of marine sediments and a variety of associated intrusive rocks; they range in age from Jurassic to late-Tertiary. The nonwater-bearing rocks all are consolidated and of low permeability. Ground water contained in them exists largely in fractures, joints, shear zones, and faults. These openings provide only minimal space for ground water storage and movement. Hence, these rocks usually provide only small quantities of water to wells. The quality of ground water in the nonwater-bearing rocks often is poor because most of the rocks are of marine origin and consequently may contain saline connate water.

Water-Bearing Units

The sediments comprising the water-bearing formations are present as beds of unconsolidated to semiconsolidated clay, silt, sand, and gravel. The water-bearing materials fall into two principal groups: the older Santa Clara Formation and the younger valley alluvium.

Santa Clara Formation

The Santa Clara Formation, which is of Plio-Pleistocene age, rests unconformably on the older rocks of the nonwater-bearing series. The formation was formed as a continental deposit that has been modified by subsequent folding and faulting; it now is exposed only along the west and east sides of Santa Clara Valley. The top of the Santa Clara Formation is encountered in the central portion of the valley at from depths of a few feet to over 200 feet (61 meters). Along the eastern side of the valley, the formation consists of obscurely bedded pebbly sandstone, siltstone, and clay. On the west side of the valley, exposures of the Santa Clara Formation show it to be composed of poorly sorted, irregularly bedded material ranging in grain size from silt to boulders.

Along the west side of the valley, the Santa Clara Formation dips eastward at from 10 to 65 degrees. Across the valley it appears to dip toward the west. Well data suggest that the permeability of the Santa Clara sediments increases from west to east, and the highest yielding wells tapping the Santa Clara Formation are on the eastern side of the valley. Beneath the central part of the valley, logs of deep wells show that the Santa Clara sediments decrease in grain size and in permeability with depth.

Valley Alluvium

The valley alluvium is of Pleistocene to Holocene age and is the most important water-bearing unit in Santa Clara Valley. The permeability of the valley alluvium generally is high; all large production water wells draw their supplies from the valley alluvium. The alluvium is composed of gravel, sand, silt, and clay, all of which are generally unconsolidated. The sand and gravel deposits have the highest transmissivities and are the major water-producing units; conversely, the layers of silt and clay have low transmissivities and act as confining beds.

The valley alluvium has been deposited principally as a series of coalescing alluvial fans by the numerous streams which drain the adjacent highlands. The alluvium in the gently sloping central portion of the valley is composed of materials which were deposited by the many streams that meandered across the plain on their way to San Francisco Bay. The deposits which underlie the plain become progressively finer-grained toward the central part of the valley. Here, there is a series of blue clay layers that become increasingly thicker toward San Francisco Bay. The blue clay is believed to be of marine origin and was deposited as bay mud during interglacial periods when sea level stood at a higher elevation than at present.

Base of Water-Bearing Deposits

Previous geologic work, published in Appendix A, identified the approximate base of the water-bearing deposits. Because the data presented in Appendix A had a contour interval of 500 feet (150 meters) (see Appendix A, Plate 4), a better definition of the base of the water-bearing deposits was required for the preparation of the mathematical model of the basin. Figure 2 in this bulletin presents a reevaluation of the data used in Appendix A, as well as an augmentation of additional data. The contour interval on Figure 2 is 100 feet (30 meters), which is of adequate detail to be used in the mathematical model. The base of the water-bearing materials could not be defined for the central and northern parts of the valley due to a lack of adequate well data. All wells used which penetrated nonwater-bearing rock are indicated on the figure.

Subsurface Deposition

The geologic information summarized in Appendix A was found to be of insufficient detail to define the aquifer system in Santa Clara Valley to the level required for the mathematical model. To tattain this level it was necessary to identify and plot the courses of the now-buried ancient stream channels in the valley. These channels act as conduits for the transmission of ground water from areas of recharge to areas of discharge. In a sense, the channels are an intricate network of pipes underlying the valley floor.

In order to identify these channels, it was first necessary to catalog all of the water wells in the north valley area for which data are available. The data were placed in a computer file and listings obtained, tabulated numerically by well location and alphabetically by well owner, which showed the well location number, owner, well depth, year drilled, well driller, and types of data on file. In all, 3,273 wells were tabulated. Most wells were found to be not over 800 feet (244 meters) in depth; the deepest well in the valley is San Jose Water Works Well No. 2 at the 17th Street Station. This well (No. 7S/1E-9D12) was drilled to a depth of 1,535 feet (468 meters) in 1910.

Computer Assisted Subsurface Geologic Evaluation

One of the principal tasks in the Santa Clara Valley area was the identification of the buried channel network within the ground water basin. This was accomplished through the application of a computer-assisted program, called the GEOLOG program, which presented subsurface data from well logs in a three-dimensional display. What is found in the subsurface is the product of a series of events that include deposition, folding, faulting, and erosion. This has resulted in the valley alluvium being composed of a sequence of meandering permeable stream channel deposits separated by less permeable silts and clays. Hence, instead of widespread aquifers separated by confining beds, there were found to be numerous tabular bodies composed of sand and gravel enclosed by silt and clay.

The main data input to the GEOLOG program were the logs of the deepest wells in each quarter-quarter section. Using this well spacing allowed for a theoretical maximum number of 4,256 data points throughout the valley. In analyzing the selected logs, it was found that the "calls" that various drillers used differed for the same material. It also was found that drillers' "calls" can be grouped, and thus a statistical analysis could be made based on these "calls". This same approach was used by Davis and others (1959), who grouped the drillers' "calls" by specific yield values in their study of the San Joaquin Valley. This grouping of "calls", modified for the Santa Clara Valley area, is presented on Table 1.

Using the groupings of drillers' "calls" shown on Table 1, the Equivalent Specific Yield value is assigned to each interval for each selected well log. Equivalent Specific Yield, or ESY, is defined as being a property of the geologic materials numerically equal to the Specific Yield but without the connotation of either the quantity of ground water contained therein or the degree of confinement. Data are then fed into the computer for all selected wells in the ground water basin. The computer, utilizing the GEOLOG program, averages the ESY values for each depth increment and prints maps of the basin for the various depth increments. The basic type of output are maps showing numeric values at each well location. These values are that of the average ESY for the particular depth increment.

A more useful printout is the symbolic type, the symbols for which are shown below:

Group	ESY Value	GEOLOG Symbol
Rock	0	*
Clay	3 to 7	.
Clay-Sand	8 to 12	-
Sand-Clay	13 to 17	+
Gravel-Sand	18 to 25	0

From this it can be seen that most clays, hardpans, and the like will appear as a dot, and the coarse-grained aquifer material will appear as a zero. Division of the materials into these basic symbols simplifies the statistical analysis as well as equalizes differences in drillers' "calls" caused by differing drillers identifying the same material by different names.

For development of geologic cross-sections, the data for each well log is processed by computer to obtain a symbolic representation of the well log based on a series of layers of uniform depth. For example, if the information is based on layers of a ten-foot (3-meter) thickness, the result is a symbolic log having a scale of one inch (2.5 cm) equals 100 feet (30 meters). The output from the computer includes the well number, ground elevation, and the elevation of the top of the log. The geologic cross-section is the combination of a ground-surface profile and symbolic logs. The cross-section is used in developing correlations of coarse-grained materials between symbolic logs.

To assist in analysis of the fine materials, another related computer program was developed. In the Reduced Clay Program, the color of the clayey materials shown on the well logs is coded in the same manner as the ESY values. In this case, reduced clays, which are those reported on the logs as being blue, gray, or green, were coded with a 99. Oxidized clays, those reported as yellow, tan, brown, or red, were coded with a zero. The computer then provided a weighted average for these two values over each ten-foot (3-meter) interval. From this, areas of marine clays (that is, reduced clays) could be differentiated from the areas of terrestrial clays (the oxidized clays).

The final cross sections, shown on Figure 3 (at end of chapter), included interpretations of both the symbolic well logs and the reduced clay logs. Shown are zones of coarse-grained aquifer materials (the stippled pattern), zones of oxidized clay (blank areas), and zones of reduced marine clays (line pattern). Individual wells are not identified due to restrictions in the California Water Code prohibiting the publication of confidential well data.

The second, and perhaps more important, use of the GEOLOG Program is the preparation of maps of the subsurface at differing elevations. In this application, the computer output is an areal map of each township for each ten-foot (3-meter) depth interval. For geologic interpretation, all townships for a given elevation are spliced together and reproduced on transparent media. The transparencies then are stacked for viewing. In Santa Clara Valley, maps were prepared for ten-foot (3-meter) intervals from a top level of +290 feet (+88 meters) to a bottom level of -550 feet (-168 meters). Preparation of maps below this latter elevation was not possible because the number of data points drops off markedly. However, it can be assumed that zones of channel material exist to an elevation of at least -1,440 feet (-439 meters) based on the log of the deepest well in the valley.

Because of the natural slope of the stream channel deposits, each channel theoretically will describe an ellipse as it passes through each horizontal level. Thus, when a sequence of levels is viewed from above, a stream channel can be seen meandering downward through the various levels. This was found to be the case for the various buried channels of Coyote Creek, Guadalupe River, Stevens Creek, and other major streams. In viewing these levels, it was found that some stream channel deposits appeared to end abruptly. Some of these discontinuities could be attributed to erosional features. However, it was noted that a number of these discontinuities appeared to fall in line. Furthermore, several alignments appeared to be extensions of mapped fault zones. Thus, a technique was developed where fault lines could be inferred. Figure 4 shows a number of fault traces which were identified through the use of the GEOLOG program. Figure 5 shows maps of the buried stream channel deposits which also were identified by the GEOLOG program. These maps include a number of elevation intervals from +100 to +50 feet (+30 to +15 meters) to -500 to -550 feet (-152 to -168 meters).

Utilization of a computer-assisted geologic analysis has greatly increased the ability to adequately analyze the aquifer system in a ground water basin. Heretofore it was necessary to employ geologic expertise in the construction of endless cross sections.

Even then, a horizontal display of the meandering stream channels was lacking. Now, through the use of these new techniques, it has become possible to undertake the detailed analysis of a ground water system at almost any level of detail, the only constraint being the level of adequate well log data.

Other ramifications of the GEOLOG method include the utilization of the numeric data for the estimation of ground water storage capacity, the assignment of transmissivity values, and a number of other geohydrologic parameters necessary for the efficient operation of a mathematical model of a ground water basin.

Faults

Geologic interpretation, using the GEOLOG program, identified many fault traces crossing Santa Clara Valley which hitherto had not been known. The faults appeared as discontinuities on the various computer printout maps of stream channels. Proof of the existence of a number of these faults was borne out in several ways. Some lines of discontinuities appeared as extensions of fault zones previously mapped in upland areas; this was the case of the Cascade Fault (see Figure 4) which had been mapped previously in the Santa Teresa Hills and is shown as the unidentified fault separating Jurassic from Cretaceous rocks on Plate 3 of Appendix A to this bulletin. The Santa Clara Fault, which also has been called the Stanford Fault, is shown as an unidentified fault on Plate 3 of Appendix A. This fault, which was inferred from geophysical data and extends from Redwood City southward to Los Altos on Plate 3, Appendix A, has been further extended on Figure 4 of this bulletin until it now is considered a major structural feature of Santa Clara Valley.

On the east side of Santa Clara Valley, the Hayward Fault previously was mapped only as far south as about Penitencia Creek. Work on the subsurface geology for this bulletin suggests that the fault does not terminate there, but rather it divides into several branches. The existence of one of these branches was further suggested by geophysical studies performed by private consultants for a foundation study for a pipeline.

Of importance to ground water movement and the construction and operation of the mathematical model was the identification of the uppermost level at which the various faults disrupt the water-bearing materials. Although this could not be precisely determined, many of the faults appear to offset buried stream channels as close as 50 feet (15 meters) below ground surface. Thus, much of the Santa Clara Valley area appears to be compartmentized with respect to ground water movement.

Storage Capacity and Transmissivity

The gross storage capacity of Santa Clara Valley ground water basin has been calculated as the theoretical volume of water that is capable of being contained between the base of the water-bearing materials and ten feet (3 meters) below ground surface; it is based on specific yield values shown in Table 1.

The portion of the gross storage capacity shown on Table 2 that can be considered as usable storage capacity has not been determined, but is limited by operational controls to prevent land subsidence and avoid excessive pumping lifts and adverse water quality effects.

Transmissivity values were estimated using a relationship between specific yield and permeability. This relationship was derived for the mathematical model of Livermore Valley and is described in detail in Department of Water Resources Bulletin No. 118-2, "Livermore and Sunol Valleys: Evaluation of Ground Water Resources", March 1974. The values for permeability which were used in the current study are presented on Table 3.

The values describe a curve, and equations describing this curve were derived for input to the computer. That part of the curve for specific yield values from 3 to 10 is described by the following equation:

$$\Delta T = \Delta D \cdot 10^{\,3.5319 \;\; \frac{7.16288}{|sy|^{-0.84}}}$$

and that part for specific yield values greater than 10 is described by the equation:

$$\Delta T = \Delta D\,(100|sy|-500),$$

where ΔT = incremental transmissivity in gallons per day per foot[1/],
ΔD = incremental depth, in feet, and
$|sy|$ = absolute value of specific yield for given interval

1/ Gpd/ft = 0.0124 m^2/d.

In addition to the above, a computer program also was written to accept specific yield data which had been coded for the GEOLOG program. Output of this latter program was the summation of the transmissivity values for each node, from bottom to top. These were directional values of transmissivity for flows along the previously identified depositional channels. For use in the mathematical model, the values were modified to apply to each nodal branch.

TABLE 1

SPECIFIC YIELD VALUES FOR DRILLERS CALLS

Type of Material and Specific Yield	Drillers Calls		
Crystalline Bedrock Specific Yield = 00 Percent	Granite Lava	Hard Rock Rock	
Clay and Shale Specific Yield = 01 Percent	Adobe Boulders in Clay Cemented Clay Clay Clayey Loam Decomposed Shale	Granite Clay Hard Clay Hard Pan Hard Sandy Shale Hard Shell Muck Mud	Shale Shaley Clay Shell Rock Silty Clay Loam Soapstone Smearey Clay Sticky Clay
Clayey Sand and Silt Specific Yield = 05 Percent	Chalk Rock Clay and Gravel Clayey Sand Clayey Silt Conglomerate Decomposed Granite Gravelly Clay Lava Clay Loam	Peat Peat and Sand Pumice Stone Rotten Conglomerate Rotten Granite Sand and Clay Sand and Silt Sand Rock Sandstone	Sandy Clay Sandy Silt Sediment Shaley Gravel Silt Silty Clay Silty Loam Silty Sand Soil
Cemented or Tight Sand or Gravel Specific Yield = 10 Percent	Black Sand Blue Sand Caliche Cemented Boulders Cemented Gravel Cemented Sand	Cemented Sand and Gravel Dead Gravel Dead Sand Dirty Pack Sand Hard Gravel	Hard Sand Heavy Rocks Lava Sand Soft Sandstone Tight Boulders Tight Coarse Gravel Tight Sand
Gravel and Boulders Specific Yield = 15 Percent	Cobbles and Gravel Coarse Gravel Boulders Broken Rocks	Gravel and Boulders Heaving Gravel Heavy Gravel Large Gravel Muddy Sand	Rocks Sand & Gravel, Silty Tight Fine Gravel Tight Medium Gravel
Fine Sand Specific Yield = 15 Percent	Fine Sand	Quicksand	Sand, Gravel, and Boulders
Sand and Gravel Specific Yield = 20 Percent	Dry Gravel Loose Gravel	Gravelly Gravelly Sand Medium Gravel	Sand and Gravel Sand Water Gravel
Coarse Sand and Fine Gravel Specific Yield = 25 Percent	Coarse Sand	Fine Gravel	Medium Sand Sand and Pea Gravel

Modified after Davis, and others (1959).

TABLE 2

GROSS GROUND WATER STORAGE CAPACITY

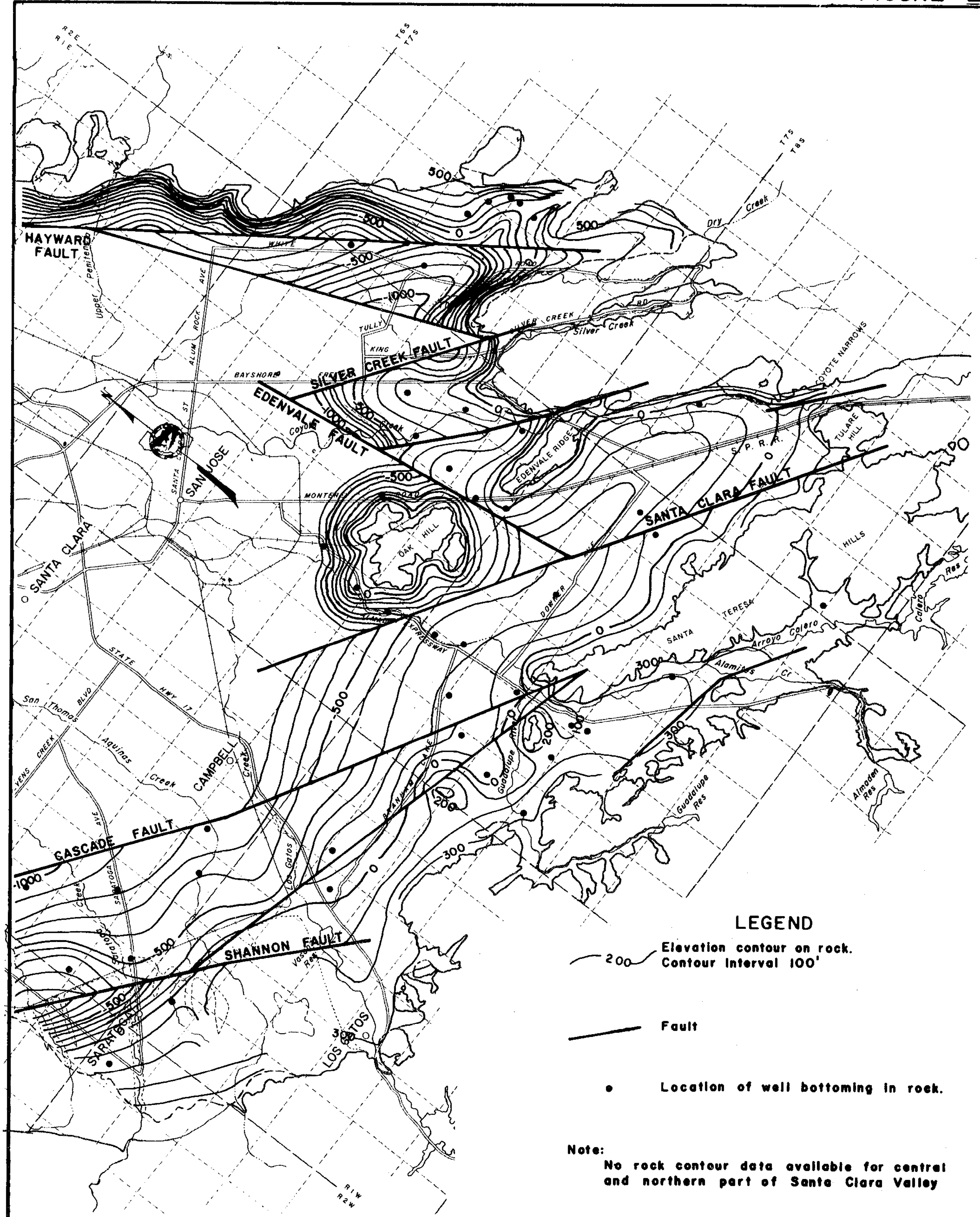
Depth below Ground Surface (feet) From	To	Gross Storage Capacity (acre-feet)	Depth below Ground Surface (meters) From	To	Gross Storage Capacity (cubic hectometers)
10	110	1,220,000	*3*	*34*	*1,504*
10	210	2,267,000	*3*	*64*	*2,795*
10	310	3,255,000	*3*	*94*	*4,013*
10	410	4,195,000	*3*	*125*	*5,172*
10	510	5,020,000	*3*	*155*	*6,190*
10	610	5,695,000	*3*	*186*	*7,022*
10	710	6,331,000	*3*	*216*	*7,806*
10	810	6,825,000	*3*	*247*	*8,415*
10	910	7,088,000	*3*	*277*	*8,740*
10	1,010	7,257,000	*3*	*308*	*8,948*

TABLE 3

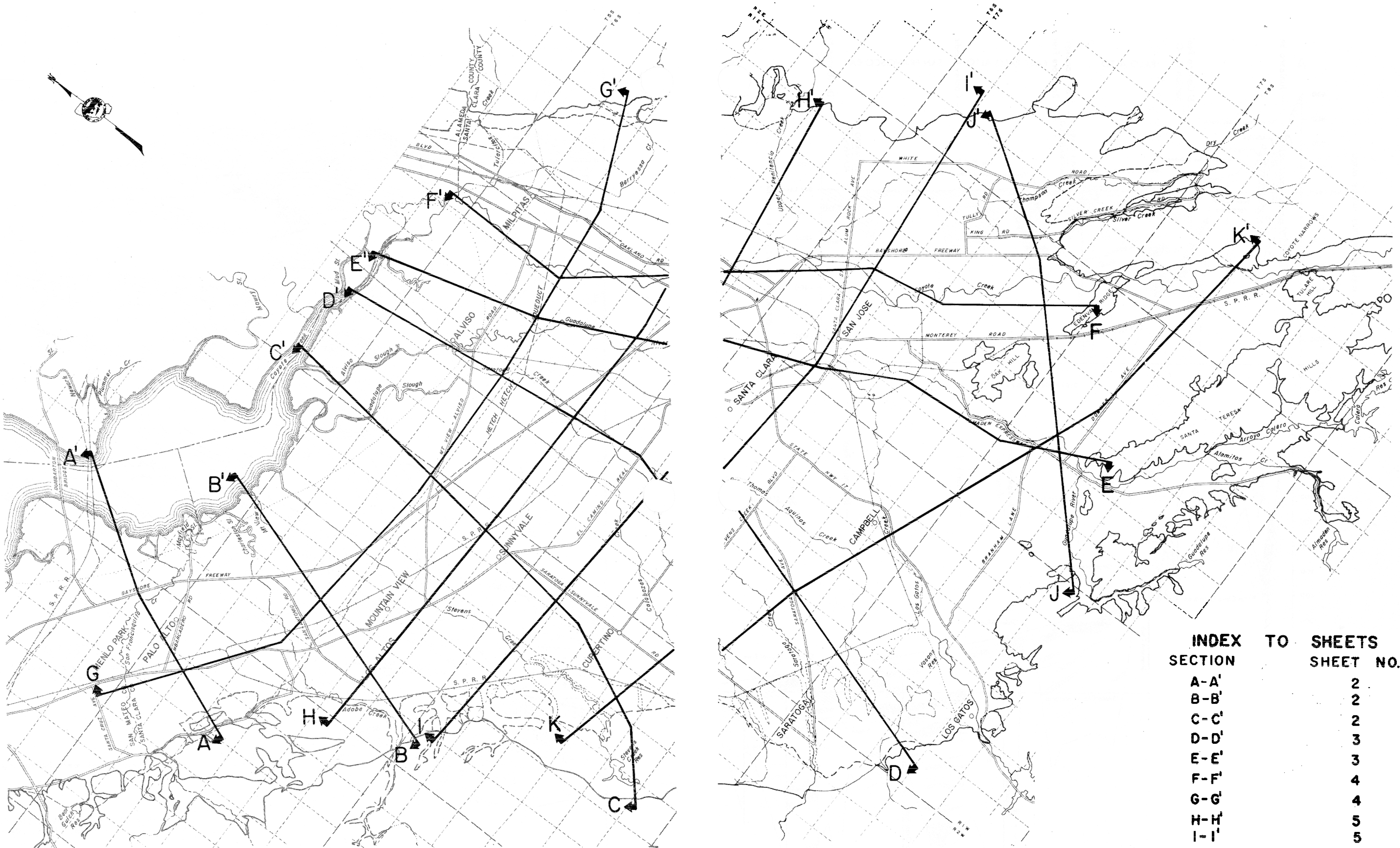
PERMEABILITY

Specific Yield (percent)	Permeability (gal/day/ft^2)	(darcys)
3	1	*0.055*
5	30	*1.65*
10	400	*22.0*
15	800	*44.0*
20	1,200	*66.0*
25	1,500	*82.5*

FIGURE 2



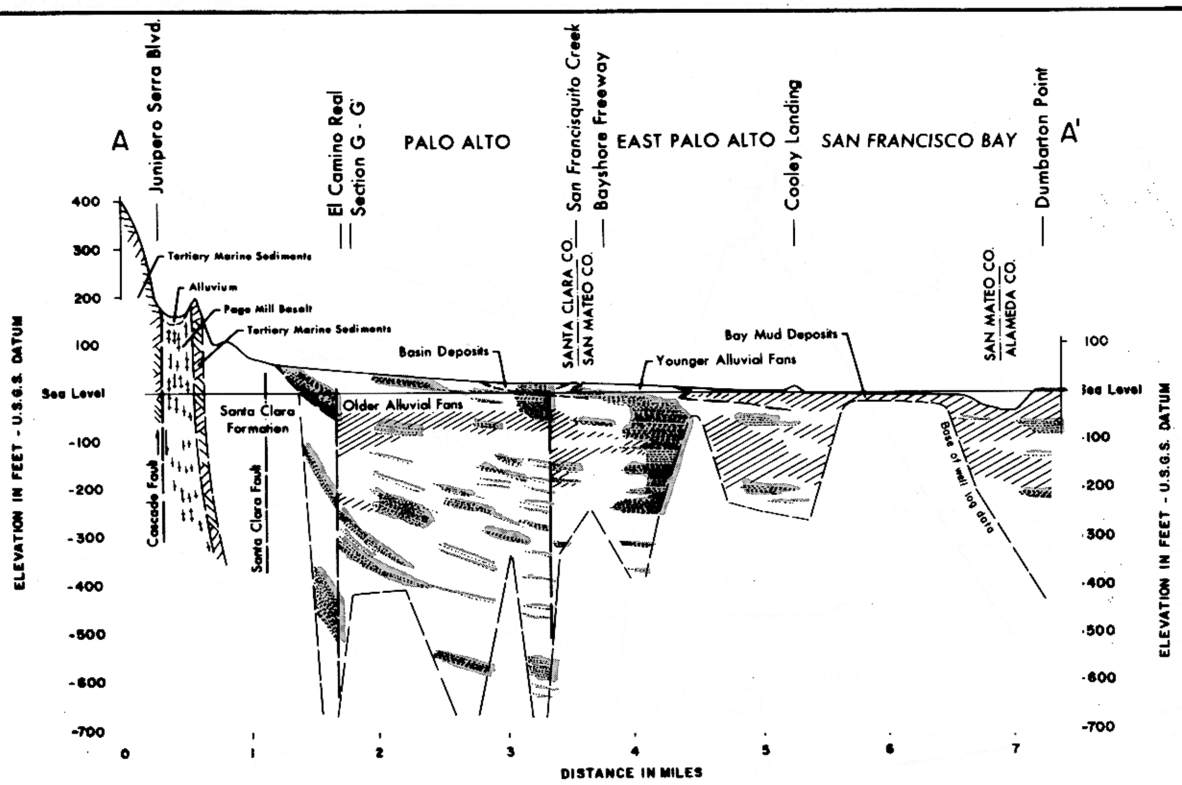
ELEVATION CONTOURS ON UPPER SURFACE
OF NONWATER-BEARING ROCK

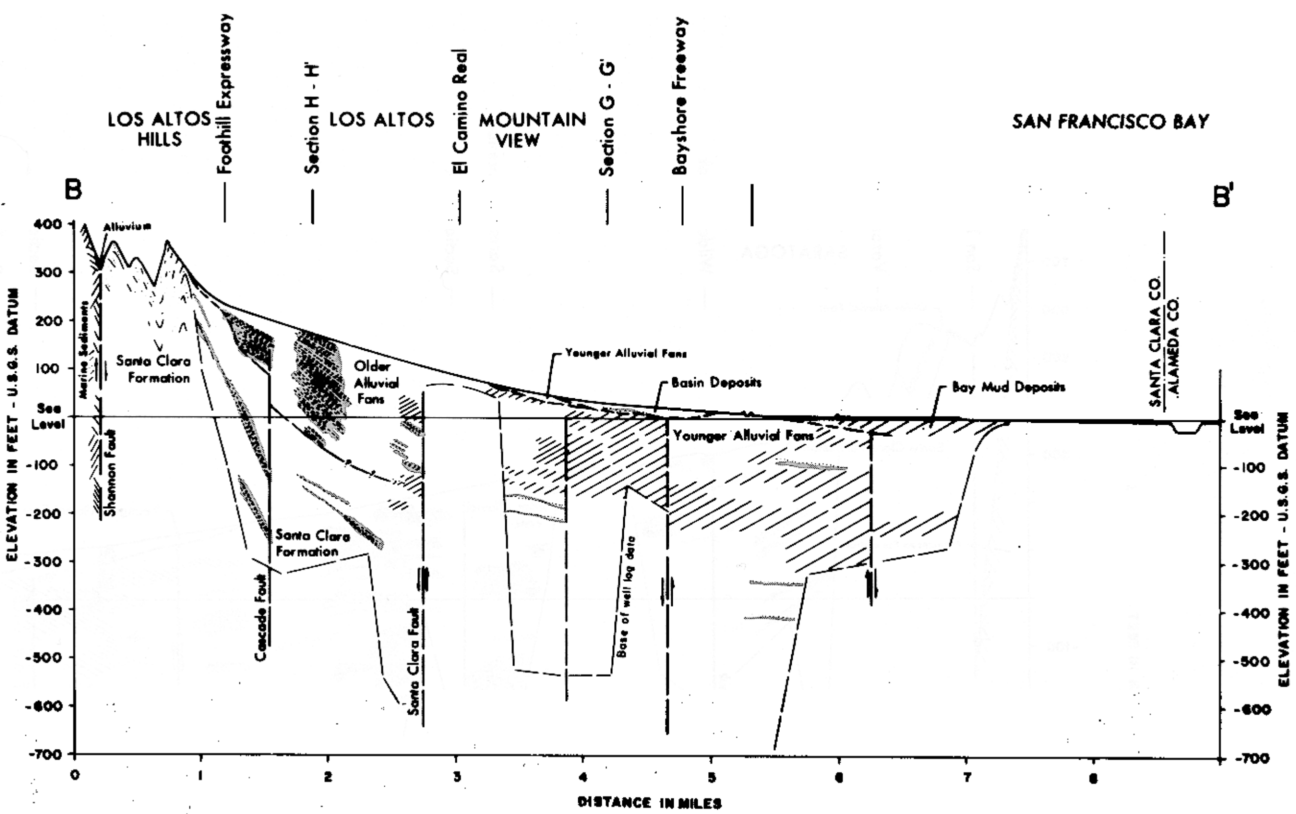


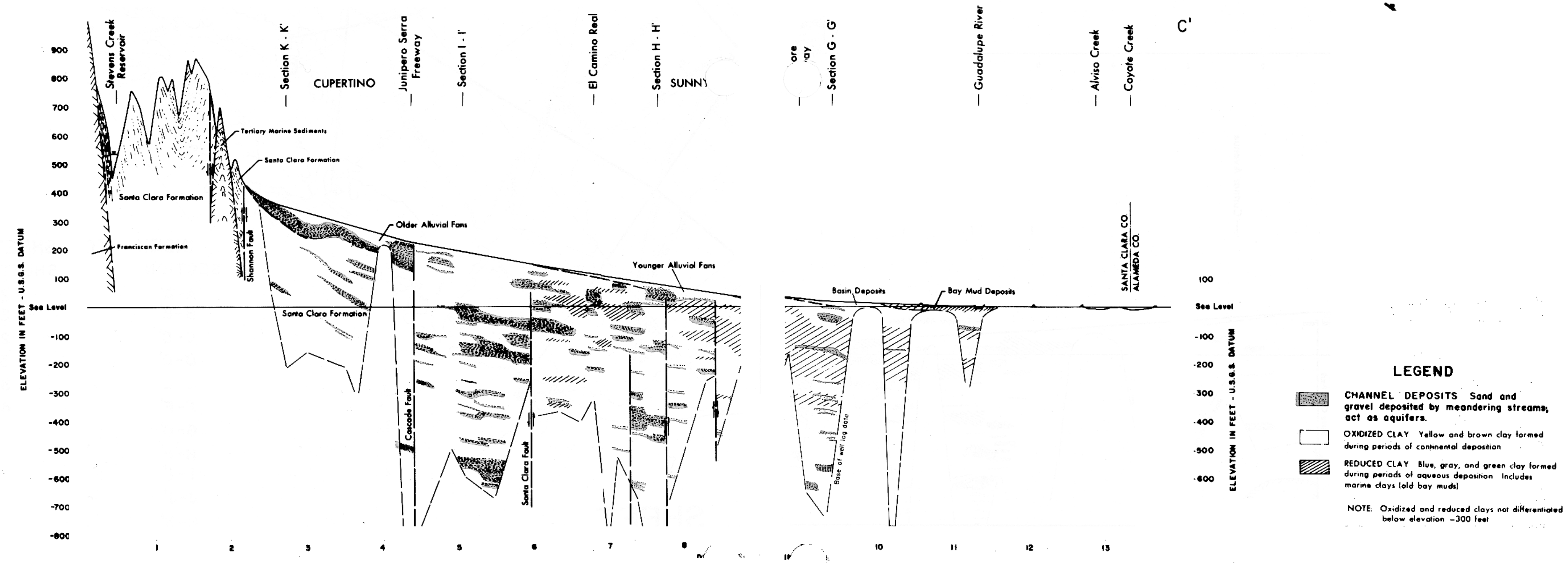
INDEX SHEET

INDEX TO SHEETS	
SECTION	SHEET NO.
A-A'	2
B-B'	2
C-C'	2
D-D'	3
E-E'	3
F-F'	4
G-G'	4
H-H'	5
I-I'	5
J-J'	6
K-K'	6

GEOLOGIC SECTIONS SANTA CLARA VALLEY

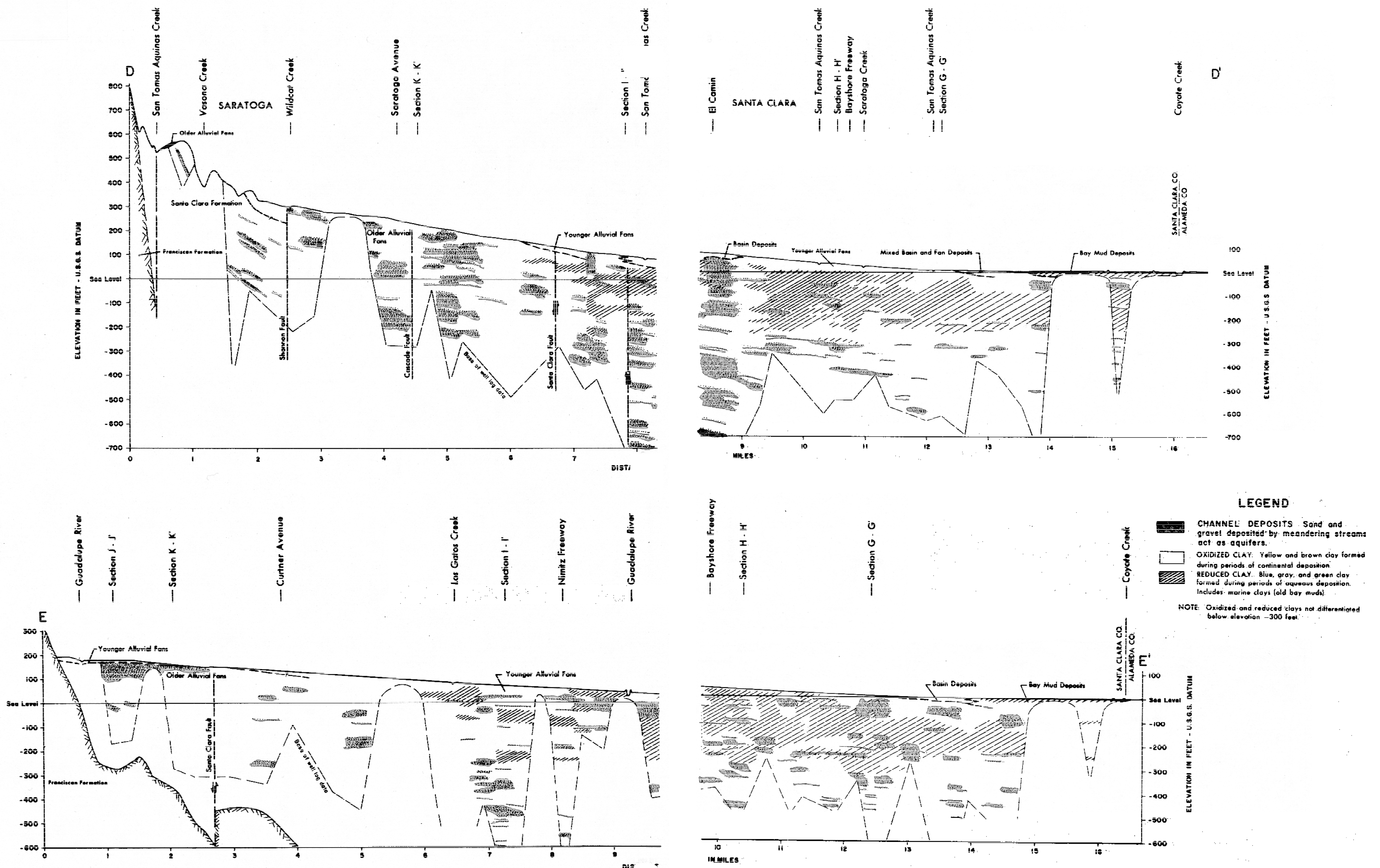






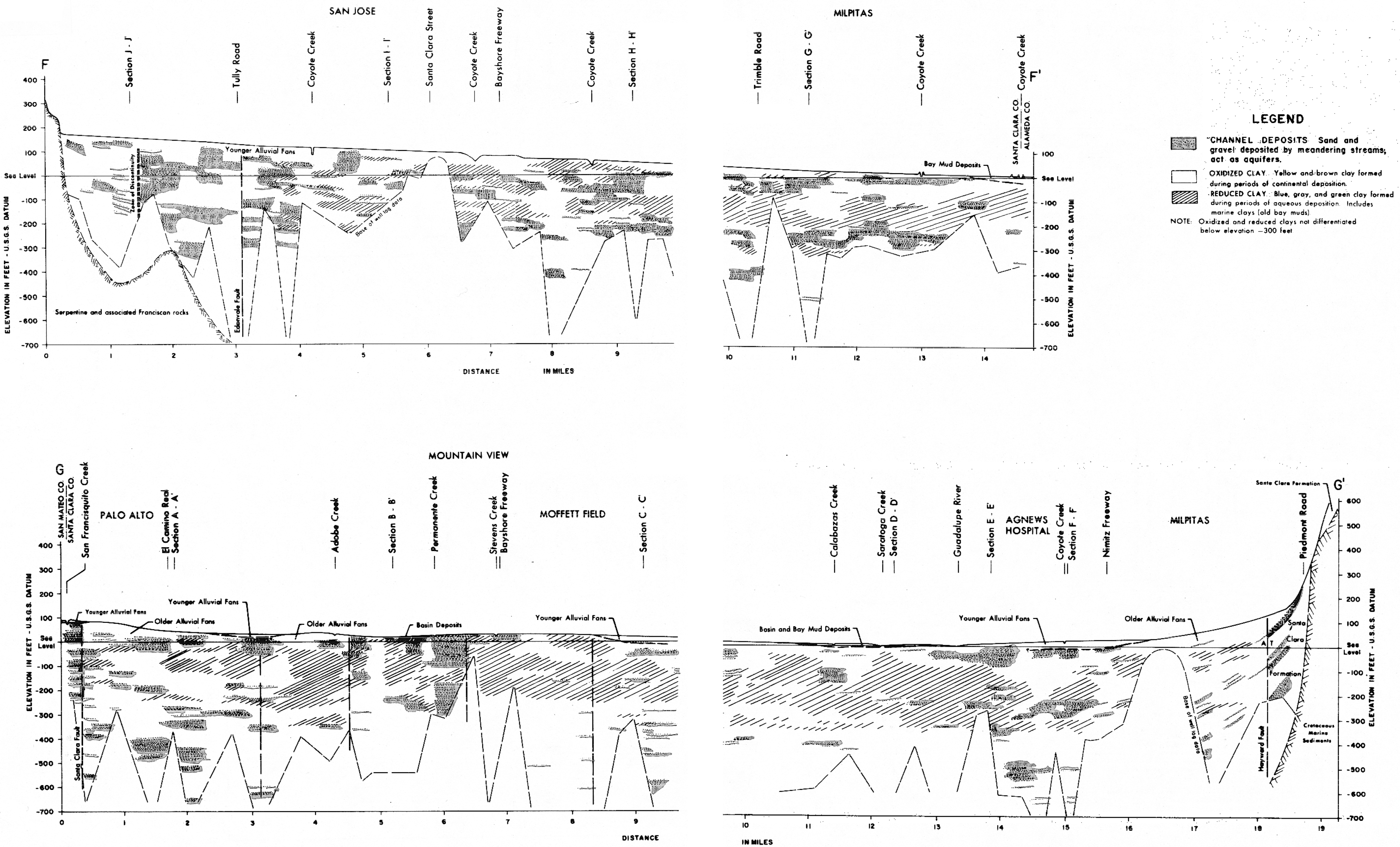
GEOLOGIC SECTIONS SANTA CLARA VALLEY

See Sheet I for location of section



GEOLOGIC SECTIONS SANTA CLARA VALLEY

See Sheet 1 for location of section



GEOLOGIC SECTIONS SANTA CLARA VALLEY